
**Gas cylinders — Refillable seamless steel
tubes of water capacity between 150 l and
3 000 l — Design, construction and testing**

*Bouteilles à gaz — Tubes en acier sans soudure rechargeables
d'une contenance en eau de 150 l à 3 000 l — Conception, construction
et essais*

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 3.

Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

International Standard ISO 11120 was prepared by Technical Committee ISO/TC 58, *Gas cylinders*, Subcommittee SC 3, *Cylinder design*.

Annexes A and B form an integral part of this International Standard.

Annexes C, D and E are for information only.

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Introduction

The purpose of this International Standard is to provide a specification for the design, manufacture, inspection and testing of tubes for worldwide usage. The objective is to balance design and economic efficiency against international acceptance and universal utility.

This International Standard aims to eliminate concern about climate, duplicate inspections and restrictions currently existing because of lack of definitive International Standards. This International Standard should not be construed as reflecting on the suitability of the practice of any nation or region.

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Gas cylinders — Refillable seamless steel tubes of water capacity between 150 l and 3 000 l — Design, construction and testing

1 Scope

This International Standard specifies minimum requirements for the material, design, construction and workmanship, manufacturing processes and tests at manufacture of refillable quenched and tempered seamless steel tubes of water capacities from 150 l up to and including 3 000 l for compressed and liquefied gases exposed to extreme world-wide ambient temperatures (normally between $-50\text{ }^{\circ}\text{C}$ and $+65\text{ }^{\circ}\text{C}$). This International Standard is applicable to tubes with a maximum tensile strength R_m of less than 1 100 MPa.

These tubes can be used alone or in batteries to equip trailers or skids (ISO modules) for the transportation and distribution of compressed gases.

This International Standard does not include consideration of any additional stresses that may occur during service or transport, e.g. bending stresses, etc.

2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this International Standard. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this International Standard are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. For undated references, the latest edition of the normative document referred to applies. Members of ISO and IEC maintain registers of currently valid International Standards.

ISO 148¹⁾, *Steel — Charpy impact test (V-notch)*.

ISO 6506²⁾, *Metallic materials — Hardness test — Brinell test*.

ISO 6892, *Metallic materials — Tensile testing at ambient temperature*.

ISO 11114-1, *Transportable gas cylinders — Compatibility of cylinder and valve materials with gas contents — Part 1: Metallic materials*.

ISO 11484, *Steel tubes for pressure purposes — Qualification and certification of non-destructive testing (NDT) personnel*.

¹⁾ To be replaced by ISO 148-1, ISO 148-2 and ISO 148-3.

²⁾ To be replaced by ISO 6506-1, ISO 6506-2 and ISO 6506-3.

3 Definitions

For the purposes of this International Standard the following definitions apply.

3.1

yield stress

value corresponding to the 0,2 % proof stress, $R_{p0,2}$

3.2

quenching

hardening heat treatment in which a tube, which has been heated to a uniform temperature above the upper critical point A_{c3} of the steel, is cooled rapidly in a suitable medium

3.3

tempering

softening heat treatment which follows quenching, in which the tube is heated to a uniform temperature below the lower critical point A_{c1} of the steel

3.4

tube

a double ended pressure gas cylinder manufactured from seamless tubing

3.5

batch

a quantity of up to 200 tubes of the same nominal diameter, thickness and design made from the same steel cast and subjected to the same heat treatment for the same duration of time

3.6

test pressure

required pressure (p_h) applied during a pressure test

3.7

design stress factor

F
ratio of the equivalent wall stress at test pressure (p_h) to guaranteed minimum yield stress (R_e)

4 Symbols

Symbol	Definition
a	calculated minimum thickness, in millimetres, of the cylindrical shell
a'	guaranteed minimum thickness, in millimetres, of the cylindrical shell
A	percentage elongation
D	nominal outside diameter of the tube, in millimetres
f	a constant in the design stress factor (see 11.3)
F	design stress factor (see 3.7)
L_0	original gauge length, in millimetres, according to ISO 6892
p_h	hydraulic test pressure, in bar ^a above atmospheric pressure
R_e	guaranteed minimum value of yield stress, in megapascals ^a
R_{ea}	value of the actual yield stress, in megapascals, determined by the tensile test
R_g	guaranteed minimum value of the tensile strength, in megapascals
R_m	actual value of tensile strength, in megapascals, determined by the tensile test
S_0	original cross-sectional area of tensile test piece, in square millimetres, according to ISO 6892
a	1 bar = 100 kPa; 1 MPa = 10 bar.

5 Inspection and testing

Evaluation of conformity is required to be performed in accordance with the relevant regulations of the country(ies) where the tubes are to be used.

In order to ensure that tubes are in compliance with this International Standard they shall be subject to inspection in accordance with clauses 9 and 10 by an authorized inspection body (hereafter referred to as "the inspector") recognized in the countries of use. The inspector shall be competent for inspection of tubes.

6 Materials

6.1 General requirements

6.1.1 Materials for the manufacture of tubes shall meet the requirements of 6.2, 6.3 and 6.4.

Steels for the fabrication of tubes shall be of nationally or internationally recognized compositions having proven reliability. These steels shall fall within one of the chemical groups as shown in annex A.

New steel compositions, and steels for which limited experience exists in tube/cylinder service, shall be fully tested and approved by a national authority and have been manufactured from not less than five casts of steel.

The manufacturer of the finished tube shall provide a detailed specification with tolerances for the supplied tubing including:

- chemical composition;

- dimensions;
- surface quality.

6.1.2 The steel used for the fabrication of tubes shall be fully killed.

6.1.3 The manufacturer of the tubing shall supply certificates of a reference heat treatment representative of the final heat treatment.

NOTE Additional requirements related to tubes for use with embrittling gases are given in clause 11.

6.2 Controls on chemical composition

6.2.1 A steel is defined by the steel-making process and by its chemical composition.

Steel-making shall be defined by reference to a given process (oxygen converter, electric arc furnace or equivalent) and to the killing method.

The chemical composition of the steel shall be defined at least by:

- the carbon, manganese and silicon contents in all cases;
- the chromium, nickel, molybdenum, vanadium or niobium contents when these are alloying elements intentionally added to the steel;
- the maximum sulphur and phosphorus contents in all cases.

The carbon, manganese and silicon contents and, where appropriate, the chromium, nickel, molybdenum, vanadium or niobium contents shall be given, with tolerances, such that the differences between the maximum and minimum values of the cast do not exceed the ranges shown in Table 1.

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Table 1 — Chemical composition tolerances

Element	Content	Permissible range
Carbon	< 0,30 %	0,06 %
	≥ 0,30 %	0,07 %
Manganese	all contents	0,30 %
Silicon	all contents	0,30 %
Chromium	< 1,50 %	0,30 %
	≥ 1,50 %	0,50 %
Nickel	all contents	0,40 %
Molybdenum	all contents	0,15 %
Vanadium	all contents	0,10 %
Niobium	all contents	0,10 %

Elements not included in the declared chemical composition shall not be deliberately added. The content of such elements shall be limited to ensure that they have no detrimental effect on the properties of the finished product.

6.2.2 The maximum sulphur and phosphorus contents in the cast analysis shall not exceed 0,020 % each and their sum shall not exceed 0,030 %. Check analyses of the supplied tubing shall not exceed 0,025 % and 0,035 % respectively.

6.2.3 The manufacturer of the finished tube shall obtain and produce certificates of cast (heat) analyses of steels supplied for the construction of tubes.

6.3 Heat treatment

6.3.1 Each tube shall be heat treated, and for each stage of treatment, i.e. quenching and tempering, the heat treatment procedure shall include a record of:

- the temperature;
- the temperature holding time;
- the cooling medium.

6.3.2 Heat treatment shall be carried out in such a way that it does not induce excessive stresses which may initiate irreversible failures in the tube.

6.3.3 The austenization temperature prior to quenching shall be defined within ± 30 °C of the temperature retained for the steel type under consideration, but it shall never be less than the upper critical point (Ac_3) of the steel concerned.

6.3.4 Quenching in media other than oil or air is permissible provided that the method produce tubes free of cracks as verified by non destructive testing.

6.3.5 The tempering temperature shall be defined within ± 30 °C of the temperature for guaranteeing specified mechanical properties but shall not be less than 540 °C.

6.4 Mechanical properties

The material of the finished tube shall satisfy the requirements of 9.2 and 10.4.

6.5 Failure to meet test requirements

6.5.1 In the event of failure to meet test requirements, retesting or reheat treatment and retesting shall be carried out as follows:

- a) If there is evidence of a fault in carrying out a test, or an error of measurement, a further test shall be performed. If the result of this test is satisfactory, the first test shall be ignored.
- b) If the test has been carried out in a satisfactory manner, the cause of test failure shall be identified.
 - 1) If the failure is considered to be due to the heat treatment applied, the manufacturer may subject all the tubes of the batch to a further heat treatment.
 - 2) If the failure is not due to the heat treatment applied, all the identified defective tubes shall be rejected or repaired by an approved method. The non-rejected and repaired tubes are then considered as a new batch.

In both cases the new batch shall be tested by the inspector. All the relevant batch tests needed to prove the acceptability of the new batch shall be performed again. If one or more tests prove even partially unsatisfactory, all the tubes of the batch shall be rejected.

6.5.2 Where reheat-treatment is required, the tubes shall be retempered or requenched and tempered.

A maximum of two re-austenitizing treatments is permitted.

Whenever tubes are reheat-treated the wall thickness can be affected by scale formation, therefore the minimum design wall thickness shall be checked in the finished tube.

7 Design

7.1 Calculation of cylindrical shell thickness

The guaranteed minimum thickness of the cylindrical shell (a') shall be not less than the thickness calculated using the Lamé-von Mises formula, as follows:

$$a = \frac{D}{2} \left[1 - \sqrt{\frac{10 F R_e - \sqrt{3} p_h}{10 F R_e}} \right]$$

where the value of F is the lesser of $\frac{0,65}{R_e/R_g}$ or 0,85

R_e/R_g shall not exceed 0,90.

Additional requirements related to tubes for use with embrittling gases are given in clause 11.

NOTE Regional international agreements may limit the magnitude of the F factor used for design.

7.2 Design of tube ends

Tube ends shall be approximately hemispherical with thickness not less than the calculated minimum wall thickness, a .

The dimensions of the tube end profiles shall be specified for each design taking into consideration the stress distribution and the manufacturing process.

To permit internal visual inspection of the tube, an adequate opening shall be provided at the neck ends. The nominal diameter of the opening shall be greater than $D/12$.

NOTE Stress analysis should be carried out to ensure that design limits are not exceeded, in particular where this opening is large.

When the tube ends are threaded, the thickness at the thread root shall be sufficient to take into account the developed stress in this part.

8 Construction and workmanship

8.1 General

The tube shall be manufactured from seamless steel tubing, typically hot rolled, extended or forged.

The ends shall be hot formed using either forging or spinning methods.

Metal shall not be added in the process of closure of the end.

Repair of defects by welding is prohibited.

8.2 Wall thickness

Each length of supplied tubing shall be examined to determine thickness.

The wall thickness at any point shall be not less than the minimum thickness specified.

Checking for wall thickness shall be by the ultrasonic method in accordance with annex B.

8.3 Surface defects

The internal and external surfaces of the finished tube shall be free from defects which would adversely affect the safe working of the tube. See annex C for examples of defects and guidance on their evaluation.

8.4 Ultrasonic examination

Each tube shall be ultrasonically examined for defects in accordance with annex B.

Examination of tubes to be used for embrittling gases (e.g. hydrogen) shall be carried out both on the supplied tubing and at completion of tube manufacture. For tubes containing other gases examination may be carried out either during or at the completion of manufacture.

8.5 End closure (fitting)

Closure of the finished tube shall be accomplished by a method other than welding, brazing or brazewelding, and shall be capable of preventing leakage.

8.6 Dimensional tolerances

8.6.1 Out-of-roundness

The out-of-roundness of the cylindrical shell, i.e. the difference between the maximum and minimum outside diameters at the same cross-section, shall not exceed 2 % of the mean value of these diameters measured at least at the quarter and mid-length locations on the tube.

8.6.2 Outside diameter

The mean external diameter shall not deviate by more than ± 1 % from the nominal design diameter; this shall be verified at the quarter and mid-length locations on the tube.

8.6.3 Straightness

The maximum deviation of the cylindrical part of the shell from a straight line shall not exceed 3 mm per metre length.

8.6.4 Eccentricity

The values of the minimum and maximum thicknesses shall differ by no more than 12,5 % from the mean value of these two thicknesses; this shall be verified at least at the quarter and mid-length locations on the tubes.

8.6.5 Length

The tolerance on the design overall length of the tube only, excluding fittings, shall not exceed the lesser of $\pm 1,5$ % or ± 50 mm.

8.6.6 Water capacity

The tolerance on the design water capacity shall be within the range $^{+10}_0$ %.

8.6.7 Mass

The tolerance on design mass of any individual tube shall not exceed ± 10 %.

If tubes are intended to constitute a battery, the tolerance on the shipment average tube mass shall be within the range $^{+5}_{-10}$ % of the unit design mass.

9 Batch tests

9.1 General requirements

The following tests and inspections shall be carried out under the responsibility of the inspector (see clause 5).

NOTE The type approval procedures normally used for cylinders of nominal water capacity less than 150 l are not applicable to the production runs for tubes.

9.2 Mechanical tests

9.2.1 General

From each production batch, test pieces shall be selected for mechanical testing from a ring of material of minimum length 200 mm taken from supplied tubing which is representative of the final condition of the tube(s), including any heat treatment.

The sample as defined above shall be placed so it is subjected at the same time as the tube(s) to the same heat treatment conditions, including with respect to single- or double-sided quenching.

9.2.2 Tensile test

The test shall be carried out in accordance with ISO 6892 on a cylindrical proportional test piece taken longitudinally (along the axis of the ring) in the ring wall and machined. The gauge length of the test piece L_0 shall be equal to $5,65\sqrt{S_0}$.

The results of the tensile test shall be at least equal to the minimum guaranteed values of the properties, and in all cases:

- R_m shall not exceed 1 100 MPa;
- the elongation after fracture shall be not less than 14 %;
- the ratio R_{ea}/R_m shall be not more than 0,95.

NOTE Additional requirements related to tubes for use with embrittling gases are given in clause 11.

9.2.3 Impact testing

9.2.3.1 Except for the requirements set out below, the test shall be carried out in accordance with ISO 148.

The test shall be carried out on three test pieces taken longitudinally from the sample ring wall. The notch shall be perpendicular to the face of the sample ring wall. The test pieces shall be machined on all six faces. If the wall thickness does not permit a final test piece width of 10 mm, the width shall be as near as practicable to the nominal thickness of the tube wall. If the wall thickness is greater than 10 mm, the test pieces shall be taken as near as practicable to the inner surface of the sample ring and their thickness limited to 10 mm.

9.2.3.2 The impact test shall be conducted at a temperature of $-20\text{ }^{\circ}\text{C}$ and the impact test values shall meet the following requirements:

- individual values $\geq 40\text{ J/cm}^2$;
- mean value $\geq 50\text{ J/cm}^2$.

If agreed between the manufacturer and purchaser, impact tests at lower temperatures may be carried out according to the condition of use provided that the foregoing test requirements are also satisfied.

9.3 Interpretation of results

Except as allowed for in 6.5, the finished tubes shall satisfy the requirements of clause 6, and of 9.2 and 10.4.

10 Tests on every cylinder

10.1 General

Following heat treatment, all tubes shall be subjected to the following tests and inspections under the responsibility of the inspector:

- either a hydraulic proof pressure test in accordance with 10.2.1 or a volumetric expansion test in accordance with 10.2.2;
- a hardness test in accordance with 10.3;
- a visual inspection in accordance with 10.4;
- a dimensional inspection in accordance with 10.5;
- ultrasonic non-destructive testing (NDT) in accordance with 10.6.

10.2 Hydraulic test

10.2.1 Proof pressure test

The hydraulic pressure in the tube shall be increased at a controlled rate until the test pressure, p_h , is reached with a tolerance of $^{+3}_0\%$. The test is normally carried out using water. All necessary precautions shall be taken to guarantee the safety of persons and property. The tube test pressure shall be held for a sufficiently long period (at least 2 min) to ascertain that there is no tendency for the pressure to decrease or for permanent visible deformation and that the tube does not leak.

The test mounting shall be so designed and arranged as to permit easy checking of the tube tightness. It shall be fitted with calibrated pressure gauge(s). Any internal pressure applied to the tube after heat treatment and before the official pressure test shall not exceed 90 % of the test pressure, p_h .

After testing the interior of the tube shall be dried to avoid oxidation.

10.2.2 Volumetric expansion test

The hydraulic pressure in the tube shall be increased at a controlled rate until the test pressure, p_h , is reached with a tolerance of $^{+3}_0$ %. The test is normally carried out using water. The tube test pressure shall be held for a sufficiently long period to ensure complete expansion of the tube, and in no case shall the pressure be held for less than 2 min. The total volumetric expansion shall be measured. The pressure shall then be released and the volumetric expansion remeasured.

The tube shall be rejected if it shows permanent expansion (i.e. volumetric expansion after the pressure has been released) in excess of 10 % of the total volumetric expansion measured at the test pressure, p_h .

The total and permanent expansion reading shall be recorded, together with the corresponding serial number of the tube tested so that the elastic expansion (i.e. total expansion minus permanent expansion), can be established for each tube.

The test apparatus shall be fitted with at least two calibrated pressure gauges arranged in a parallel configuration to check the accuracy of the pressure applied to the tube. Any internal pressure applied to the tube after heat treatment and before the official pressure test shall not exceed 90 % of the test pressure, p_h .

After testing, the interior of the tube shall be dried to avoid oxidation.

10.3 Hardness testing

The purpose of this test is to check the homogeneity of the heat treatment of a tube batch.

A Brinell hardness test shall be conducted on each tube in accordance with ISO 6506, preferably with a ball having a diameter of 10 mm and at a 29 420 N (3 000 kgf) load, except when circumstances do not permit.

The conversion of hardness test results into tensile strength values shall be determined by the tube manufacturer, using test pieces representative of the manufactured tubes.

Hardness shall be measured and recorded at four diametrically opposed points in at least three circular cross-sections distributed over the whole length of each tube at intervals of not greater than 3 m.

The average of the results on each circular cross-section shall be within the minimum-maximum tensile strength range guaranteed by the manufacturer. The values may be plotted on a diagram to identify their position.

10.4 Visual inspection

The inner and outer surfaces of each finished tube shall be inspected visually for cleanliness and defects in accordance with 8.3.

This is intended to check, in particular for the inner surface, that:

- no foreign matter or grease is present;
- no liquid or moisture is present inside the tube;
- no shoulder cracks are present.

Light, tightly adhering scale or blush rust oxide is acceptable unless expressly prohibited by the final application.

10.5 Dimensional inspection

10.5.1 Thickness

Inspection of wall thickness to check conformity with the requirements of 8.2 and 8.6.4 shall be carried out on each tube at any manufacturing stage chosen by the manufacturer. The manufacturer shall ensure that no noticeable reduction in thickness takes place in processing after this stage.

10.5.2 Diameter and length

Checks of the outside diameter and length shall be carried out on each finished tube to check conformity with the requirements of 8.6.1 to 8.6.3 and in 8.6.5.

10.5.3 Water capacity and mass

The water capacity and mass shall be checked on each tube for conformity with the requirements of 8.6.6 and 8.6.7.

10.6 Ultrasonic non destructive test

The internal and external surface of each finished tube or tube prior to end forging shall be submitted to inspection over 100 % of the cylindrical wall part to ensure compliance with the requirements specified in 8.2 and 8.4.

10.7 Certificates

Each batch of tubes shall be covered by a certificate signed by the inspecting authority's representative to the effect that the tubes meet the requirements of this International Standard in all respects. An example of a suitably worded certificate is given in annex D. A checklist of tests is given in annex E.

Copies of the certificate shall be retained by the inspection body and the manufacturer. The original certificate shall be retained by the inspecting authority and the copies by the manufacturer in accordance with the regulations of the relevant statutory authority.

11 Special requirements for tubes for embrittling gases

11.1 General

Tubes intended for the transport of gases which have a risk of hydrogen embrittlement (in accordance with ISO 11114-1) shall meet the following particular requirements in addition to the specifications in clauses 6 to 10.

11.2 Materials

The suitability for use in the production of tubes intended to contain embrittling gases and made of steels of given chemical compositions and heat treatments shall be checked. The steels shall meet the requirements of clause 6 and the additional requirements of 11.5; specifically in no case shall R_m exceed 950 MPa.

11.3 Design

The guaranteed minimum thickness of the cylindrical shell shall be calculated by the Lamé-von Mises formula in accordance with 7.1 except that:

$$F = \frac{f}{R_e / R_g}$$

where

$$f = 0,65 \text{ for } R_m \leq 890 \text{ MPa}$$

$$f = 0,61 \text{ for } 890 < R_m \leq 950 \text{ MPa}$$

$$R_e / R_g \text{ shall not exceed } 0,85.$$

11.4 Construction and workmanship

11.4.1 General

Special attention shall be given to the tube shoulders to ensure that their particular shape does not induce high stresses.

The design of openings and of adaptors, including gaskets, shall permit variations in the tube dimensions (e.g. its volume) during filling.

The internal thread and the transition area shall be manufactured with special care to avoid stress concentrations.

11.4.2 Surface defects

11.4.2.1 The inner and outer surfaces of each blank of supplied tubing shall be submitted to careful inspection prior to end closing-in by forging. In particular, the inner surfaces and edges of the blanks shall be free from any critical defects which exceed the test level.

Surface inspection shall be conducted using ultrasonic non-destructive testing in accordance with annex B.

11.4.2.2 After forging of the tube ends, the internal surface of the neck and shoulder shall be examined for folds and cracks by means of an endoscope, introscope, dentist mirror or other suitable appliance.

The surface shall be free from cracks.

Folds that are clearly visible as depressions having rounded peaks and roots shall not be deemed to constitute defects, but those which have sharp profiles, or whose shape cannot definitely be identified, particularly those that are only discernible as a crack or a line of oxide on the tube surface and extend into the threaded portion, are not acceptable and shall be removed.

11.4.2.3 All surface imperfections revealed by these examinations shall be removed by machining, grinding or any appropriate procedure except welding. Great care shall be taken to avoid introducing new injurious defects such as striations.

After such a repair, the wall thickness shall be re-checked for conformity with 7.1.

11.5 Mechanical tests

11.5.1 Tensile and impact tests

Tubes shall be fully tempered to satisfy the following:

- a) the results of the tensile test in 9.2.2 shall meet the following requirements:
 - R_m shall not exceed: 890 MPa if $f = 0,65$ or 950 MPa if $f = 0,61$;
 - elongation after fracture shall be not less than 16 %;
 - ratio R_{ea}/R_m shall not exceed 0,90;
- b) for the impact test in 9.2.3 at the test temperature each test specimen shall exhibit a lateral expansion greater than 0,4 mm, or the fracture face shall have a generally ductile appearance at visual inspection, i.e. the crystalline appearance of the fracture shall not exceed 50 %.

This may be confirmed by determining the transition temperature of the products under inspection.

11.5.2 Hardness test

11.5.2.1 The purpose of the hardness test is to check the homogeneity of a tube and the level of its mechanical properties after heat treatment.

The following shall be checked:

- that the results of hardness readings on one circumference of the outer wall, in conformity with 10.3, do not differ by more than 30 HB;
- that at any point of the tube surface, the steel tensile strength as calculated from a conversion of Brinell hardness values is not greater than the maximum guaranteed value of the tensile strength specified in 11.5.1.

11.5.2.2 The hardness test shall be conducted under the conditions defined in 10.3.

12 Marking

Each tube shall be stamped on the shoulder or on a reinforced part of the tube or on a permanently fixed collar or neck ring in accordance with the relevant marking requirements of the countries of use.

NOTE An ISO Standard for stamp marking is in preparation.

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Annex A (normative)

ISO High-pressure gas tube/cylinder chemistry groupings

Values in percent

Element	Group I	Group II	Group III	Group IV
C	0,32/0,48	0,25/0,40	0,35/0,50	0,15/0,50
Mn	0,90/1,65	0,40/1,00	0,60/1,05	0,40/0,70
P	0,025 max.	0,025 max.	0,025 max.	0,020 max.
S	0,025 max.	0,025 max.	0,025 max.	0,015 max.
Si	0,10/0,50	0,10/0,45	0,15/0,40	0,10/0,40
Ni	0,40 max. ^a	—	—	0,15/0,40
Cr	0,40 max. ^a	0,80/1,20	0,85/1,20	2,25/2,75
Mo	0,10 max. ^a	0,15/0,35	0,15/0,30	0,15/0,60
V	—	—	—	0,15/0,30 ^b

NOTE The steels shall be fully killed with a sufficient amount of nitrogen binding elements (e.g. Al \geq 0,015 %)

^a Ni + Cr + Mo = 0,63 max.

^b V optional.

Annex B (normative)

Ultrasonic inspection

B.1 General

This annex is based on techniques used by tube manufacturers. Other techniques of ultrasonic inspection may be used, provided these have been demonstrated to be suitable for the manufacturing method.

B.2 Equipment and personnel requirements

The ultrasonic testing equipment shall be capable of at least detecting the reference standard as described in B.3.2. It shall be serviced regularly in accordance with the manufacturer's operating instructions to ensure that its accuracy is maintained. Inspection records and approval certificates for the equipment shall be maintained.

The operation of the test equipment shall be by trained personnel supervised by personnel certified at least to level 2 of ISO 11484.

The inner and outer surfaces of any tube which is to be tested ultrasonically shall be in a condition suitable for an accurate and reproducible test.

For flaw detection the pulse echo system shall be used. For thickness measurement either the resonance method or the pulse echo system shall be used. Either contact or immersion techniques of testing shall be used.

A coupling method which ensures adequate transmission of ultrasonic energy between the testing probe and the cylinder shall be used.

B.3 Flaw detection of the cylindrical part

B.3.1 Procedure

The tubes to be inspected and the search unit shall have a rotating motion and translation relative to one another such that a helical scan of the cylinder will be described. The velocity of rotation and translation shall be constant within $\pm 10\%$. The pitch of the helix shall be less than the width covered by the probe (at least a 10% overlap shall be guaranteed) and be related to the effective beam width such as to ensure 100% coverage at the velocity of rotation and translation used during the calibration procedure.

An alternative scanning method may be used for transverse defect detection, in which the scanning or relative movement of the probes and the work piece is longitudinal, the sweeping motion being such as to ensure a 100% surface coverage with 10% overlap of the sweeps.

The tube wall shall be tested for longitudinal defects with the ultrasonic energy transmitted in both circumferential directions and for transverse defects in both longitudinal directions.

When optional testing is carried out on the transition areas between the wall and neck and/or wall and base, this may be conducted manually if not carried out automatically.

The effectiveness of the equipment shall be periodically checked by passing a reference standard through the test procedure. This check shall be carried out at least at the beginning and end of each shift. If during this check the presence of the appropriate reference notch is not detected then all tubes tested subsequent to the last acceptable check shall be retested once the equipment has been correctly adjusted.

B.3.2 Reference standard

A reference standard of convenient length shall be prepared from tubing of similar diameter and wall thickness range, of material with the same acoustic characteristics and surface finish as the tube to be inspected. The reference standard shall be free from discontinuities which may interfere with the detection of the reference notches.

Reference notches both longitudinal and transverse, shall be machined on the outer and inner surface of the standard. The notches shall be separated such that each notch can be clearly identified.

Dimensions and shape of notches are of crucial importance for the adjustment of the equipment (see Figures B.1 and B.2).

The length of the notches (E) shall be no greater than 50 mm long.

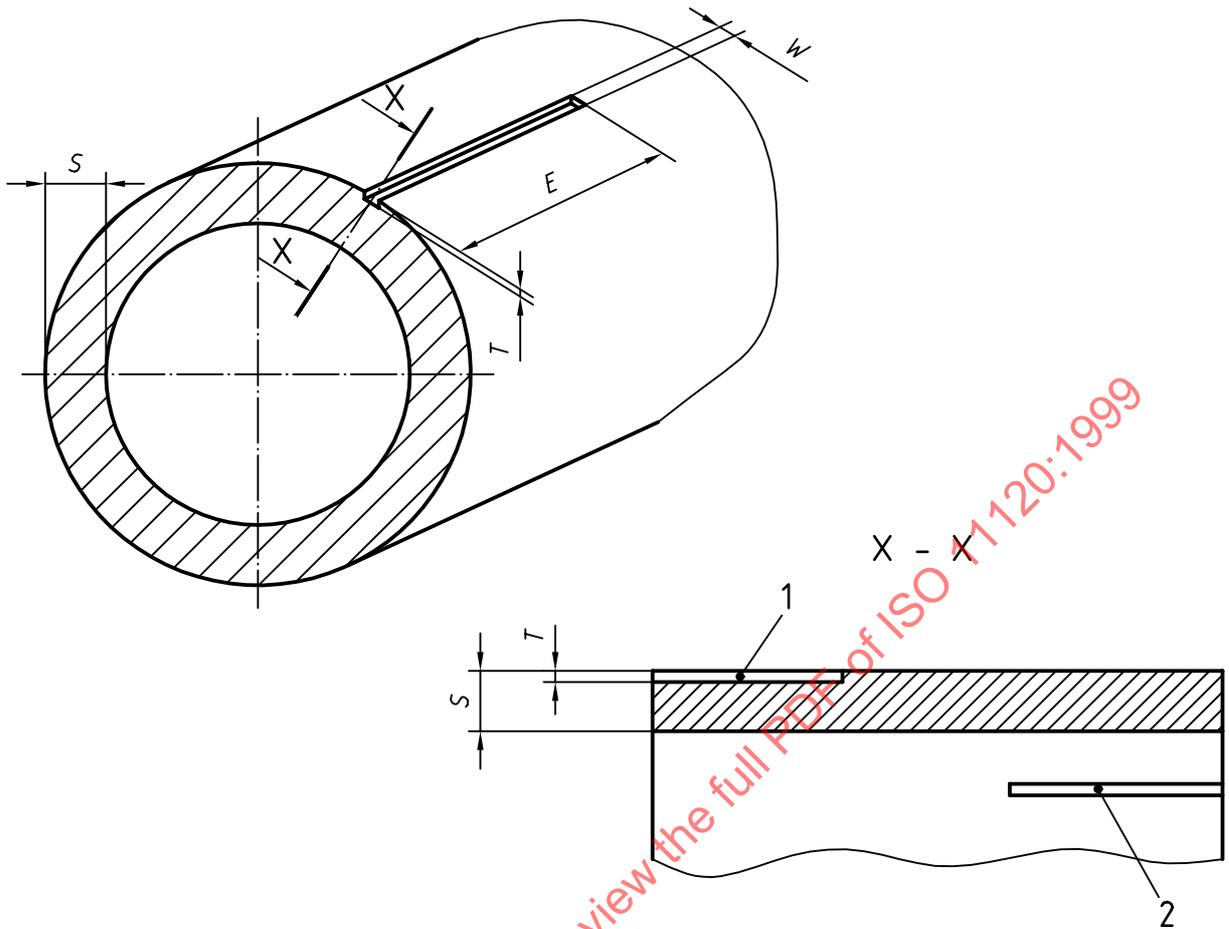
The width (W) shall be no greater than twice the nominal depth (T). However, where this condition cannot be met a maximum width of 1 mm is acceptable.

The depth of the notches (T) shall be equal to $5\% \pm 0,75\%$ of the nominal wall thickness (S), with a minimum of 0,3 mm and a maximum of 1,0 mm, over the full length of the notch. Runouts at each end are permissible.

The notch shall be sharp edged at its intersection with the surface of the cylinder wall. The cross-section of the notch shall be rectangular except where spark erosion machining methods are employed; then it is acknowledged that the bottom of the notch will be rounded.

The shape and dimensions of the notch shall be verified by an appropriate method.

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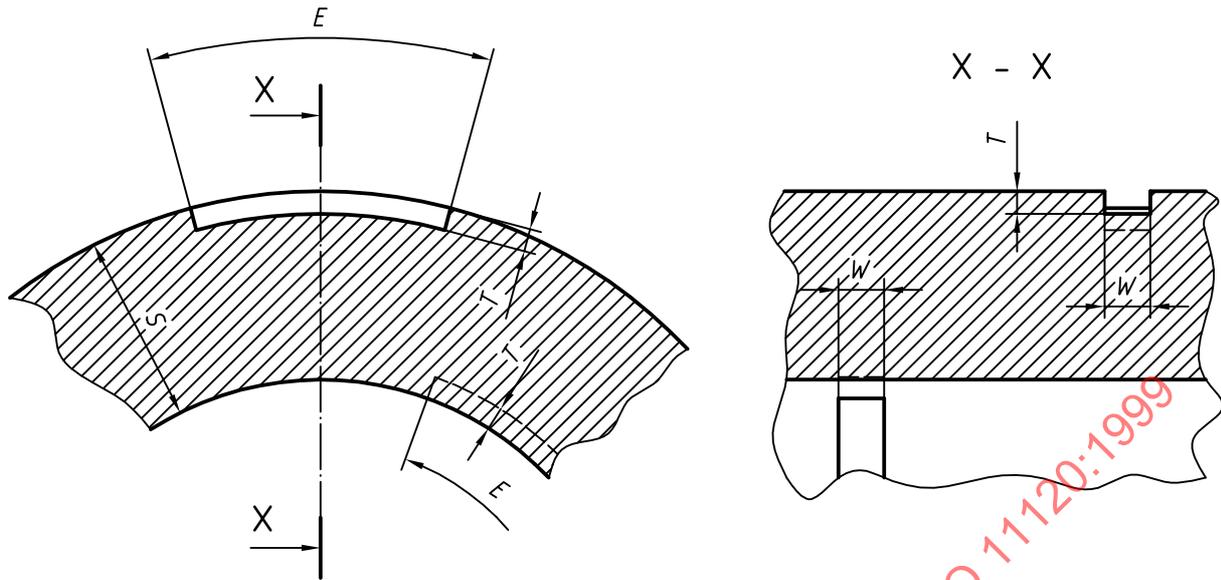


NOTE $T \leq (5\% \pm 0,75\%)S$ but ≤ 1 mm and $\geq 0,3$ mm
 $W \leq 2T$, but if not possible then ≤ 1 mm
 $E \leq 50$ mm

Key

- 1 Outside reference notch
- 2 Inside reference notch

Figure B.1 — Design details and dimensions of the reference notches for longitudinal defects



NOTE $T \leq 5 \% \pm 0,75 \% S$ but ≤ 1 mm and $\geq 0,3$ mm
 $W \leq 2T$, but if not possible then ≤ 1 mm
 $E \leq 50$ mm

Figure B.2 — Schematic representation of the reference notches for circumferential defects

B.3.3 Calibration of equipment

Using the reference standard described in B.3.2, the equipment shall be adjusted to produce clearly identifiable indications from inner and outer surface notches. The amplitude of the indications shall be as near equal as possible. The indication of smallest amplitude shall be used as the rejection level and for setting visual, audible, recording or sorting devices. The equipment shall be calibrated with the reference standard or probe, or both, moving in the same manner, in the same direction and at the same speed as will be used during the inspection of the tube. All visual, audible, recording or sorting devices shall operate satisfactorily at the test speed.

B.4 Wall thickness measurement

If the measurement of the wall thickness is not carried out in another stage of production, the cylindrical part shall be 100 % examined to ensure that the thickness is not less than the guaranteed minimum value.

B.5 Interpretation of results

Tubes with indications which are equal to or greater than the lowest of the indications from the reference notches shall be withdrawn. This comparison shall be made between the indications from the tube and those from the reference notch in the same orientation and on the same face e.g. a transverse inside defect shall be compared with the transverse inside reference notch. The cause of the indication shall be identified and if possible removed. After removal the cylinders shall be re-subjected to ultrasonic flaw detection and thickness measurement, conducted either automatically or manually.

Where a manual retest is conducted the hand scanning equipment shall be calibrated using a calibration standard described in B.3.2. The tube surfaces shall be tested for longitudinal defects with the ultrasonic energy transmitted in both circumferential directions, and for transverse defects in both longitudinal directions. To ensure complete

coverage of the reconditioned area, the manual scan shall overlap at least 15 %, and the scan shall not exceed a rate of 150 mm·s⁻¹.

Any tube which is shown to be below the design minimum wall thickness shall be rejected.

B.6 Certification

The ultrasonic testing shall be certified by the tube manufacturer.

Every tube, which has passed the ultrasonic testing in accordance with this specification shall be stamp marked with the symbol 'UT'.

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Annex C (informative)

Description, evaluation of manufacturing defects and conditions for rejection of seamless steel tubes at time of visual inspection

C.1 Introduction

Several types of defect can occur during the manufacturing of a seamless steel tube.

Such defects can be mechanical or material. They can be due to the basic material used, the manufacturing process, heat treatments, manipulations, necking, machining or marking operations and other occurrences during manufacture.

The aim of this annex is to identify the manufacturing defects most commonly met and to provide general guidelines to the inspectors that perform the visual inspection.

Nevertheless extensive field experience, good judgement and independence from production are necessary by the inspector to detect and to be able to evaluate and judge a defect at the time of the visual inspection.

C.2 General

C.2.1 It is essential to perform the visual internal and external inspection in good conditions.

The surface of the metal and particularly of the inner wall should be completely clean, dry and free from oxidation products, corrosion, scale, etc., since these could obscure other more serious defects. Where necessary, the surface shall be cleaned under closely controlled conditions by suitable methods before further inspection.

Appropriate sources of illumination with sufficient intensity should be used.

After the cylinders have been closed and the threads have been cut, the internal neck area should be examined by means of an introscope, dental mirror or other suitable appliance.

C.2.2 Small defects may be removed by local dressing, grinding, machining, or other appropriate method.

Great care should be taken to avoid introducing new injurious defects.

After such a repair the cylinders should be re-examined and, if necessary, the wall thickness rechecked.

C.3 Manufacturing defects

The most commonly found manufacturing defects and their definitions are listed in Table C.1.

Rejection limits for repair or reject are also included in Table C.1. These rejection limits are established following considerable field experience. They apply to all sizes and types of tube and service conditions. Nevertheless, some customer specifications, some types of tube or some special service conditions may require more stringent criteria.

C.4 Rejected cylinders

All rejected tubes should be rendered unserviceable for their original application.

It may be possible to produce tubes for different service conditions from rejected cylinders.

Table C.1 — Manufacturing defects

Defect	Description	Conditions and/or actions	Repair or reject
Bulge	Visible swelling of the wall	All cylinders with such a defect	Reject
Dent(flats)	A depression in the wall that has neither penetrated nor removed metal (see Figure C.1) (see also excessive grinding or machining)	When the depth of the dent exceeds 2 % of the external diameter of the tube When the depth of the dent is greater than 1 mm and the diameter of the dent is less than 30 times its depth NOTE On small diameter tubes these general limits may have to be adjusted. Consideration of appearance also plays a part in the evaluation of dents, especially in the case of small tubes.	Reject Repair possible
Cut, gouge metallic or scale impression	An impression in the wall where metal has been removed or redistributed (due basically to the introduction of foreign bodies on the mandrel or matrix during extrusion or drawing operations)	Inside defect: If not superficial with sharp notches more than 5 % of wall thickness NOTE Consideration of appearance and localisation (in thicker parts with lower stresses) can be taken into account). Outside defect: When the depth exceeds 5 % of the wall thickness or when the length exceeds 5 times the wall thickness	Reject Repair possible (see C.2.2)
Dent containing cut or gouge	A depression in the wall which contains a cut or gouge (see Figure C.2)	All cylinders with such defects	Reject
Excessive grinding or machining	Local reduction of wall thickness by grinding or machining	When the wall thickness is reduced to below the minimum design thickness When it results in the formation of a dent	Reject See "dent" above
Rib	A longitudinal raised surface with sharp corners (see Figure C.3)	Inside defect: If height exceeds 5 % of wall thickness and if the length exceeds 10 % of the length of the tube Exterior defect: When the height exceeds 5 % of the wall thickness or when the length exceeds 5 times the thickness of the tube	Repair if possible or reject Repair if possible or reject (see C.2.2)

(continued)

Table C.1 — Manufacturing defects (continued)

Defect	Description	Conditions and/or actions	Repair or reject
Groove	A longitudinal notch (see Figure C.4)	Inside defect: If depth exceeds 5 % of wall thickness and if the length exceeds 10 % of the length of the tube Outside defect: When the depth exceeds 5 % of wall thickness or when the length exceeds 5 times the thickness of the tube	Repair if possible or reject Repair if possible or reject (see C.2.2)
Lamination	Layering of the material within the tube wall and sometimes appearing as a discontinuity, crack, lap or bulge at the surface (see Figure C.5)	Inside defect: All tubes with such a defect Outside defect: All tubes with such a defect	Repair if possible Repair if possible or reject (see C.2.2)
Crack	Split, material separation	When not removable with thickness tolerance: When removable within thickness tolerance:	Reject Repair
Neck cracks	Appear as lines which run vertically down the thread and across the thread faces (they should not be confused with tap marks or thread machining marks) (see Figure C.6)	All tubes with such defects	Reject
Shoulder folds	Folding with peaks and troughs situated in the internal shoulder area, which can propagate into the threaded area of the shoulder (see Figure C.7).	Folds or cracks that are visible as a line of oxide running into the threaded portion should be removed by a machining operation until the lines of oxide are no longer visible (see Figure C.7) After machining, the whole area should be reinspected carefully and the wall thickness verified	Repair
and/or Shoulder cracks	Cracks can start from folds in the internal shoulder area and propagate into the cylindrical machined or threaded area of the shoulder (Figure C.8 shows exactly where shoulder cracks start and how they propagate)	If folding or lines of oxide have not been removed by machining, if cracks are always visible or if wall thickness is unsatisfactory:	Reject
		Folds which extend beyond the machined area and are clearly visible as open depressions where no oxides have been trapped in the metal, should be accepted provided that the peaks are smooth and the root of the depression is rounded	Acceptable

(continued)

Table C.1 — Manufacturing defects (concluded)

Defect	Description	Conditions and/or actions	Repair or reject
“Orange peel” surface	Orange peel appearance due to discontinuous metal flow, usually in the base	If sharp cracks are visible in the orange peel surface	Reject
Internal threads damaged or out of tolerance	Neck threads damaged with dents, cuts, burrs or out of tolerance	When the design permits it, threads may be re-tapped and re-checked by the appropriate thread gauge and carefully visually re-examined. The appropriate number of effective threads should be achieved If not repairable	Repair Reject
Pitting	Severe surface corrosion	All tubes with such defects visible after shot blasting	Reject
Non conformity with design drawing		All tubes presenting such a defect	Repair if possible or reject
Neck ring not secure	Neck ring turns under application of low torque, or pulls off under low axial load. (See ISO 11117 for guidance)	All tubes presenting such a defect	Repair if possible or reject
Arc or torch burns	Partial burning of the tube metal, the addition of weld metal or the removal of metal by scarfing or cratering	All tubes presenting such a defect	Reject

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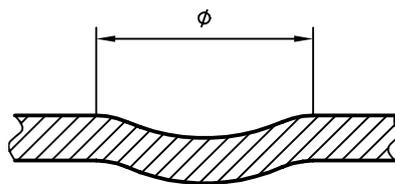


Figure C.1 — Dent



Figure C.2 — Dent containing cut or gouge

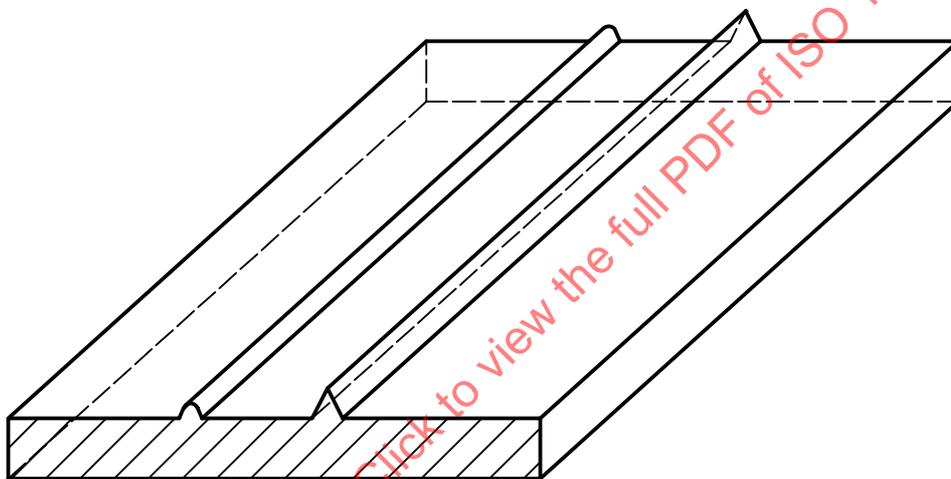


Figure C.3 — Rib

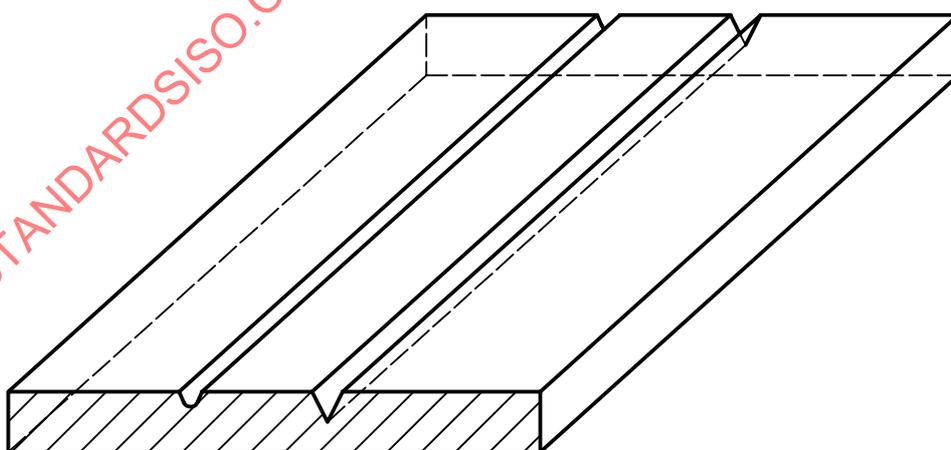


Figure C.4 — Groove

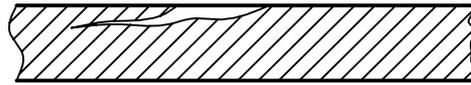
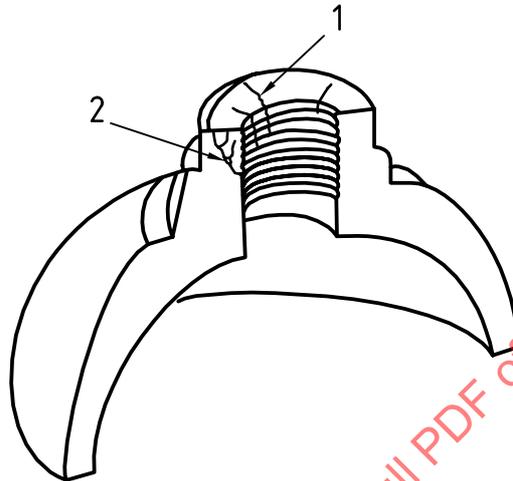


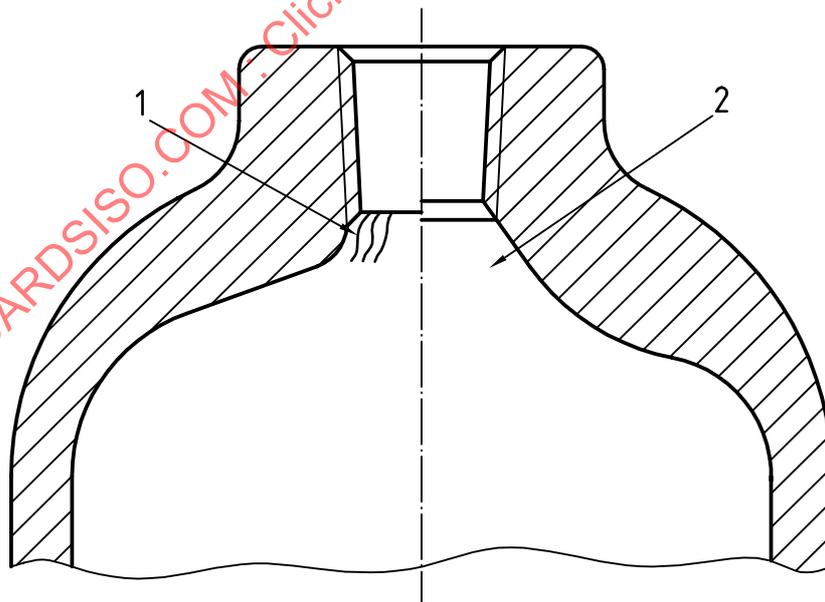
Figure C.5 — Lamination



Key

- 1 Neck cracks
- 2 Propagated crack in the neck

Figure C.6 — Neck cracks



Key

- 1 Folds or cracks
- 2 After machining

Figure C.7 — Tube shoulder folds or cracks before and after machining